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ABSTRACT

Several forecasters project significant shortages of doctoral engineers, physical scientists, mathematicians, and computer scientists through much of the next decade. This paper discusses the shortage of doctoral scientists and engineers and the solution to the problem. The possibility of hiring foreign graduates and recruiting minorities and women in science and engineering areas is examined. An intervention program for elementary and secondary schools is suggested for solving the future problems. Lists 11 references. (YP)

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RECRUITING DOCTORAL SCIENTISTS AND ENGINEERS TODAY AND TOMORROW

ED313218

by

Betty M. Vetter

Occasional Paper 89-2

February 1989

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Adapted from a
Presentation on September 19, 1988
to
General Electric Doctoral Recruiters

General Electric Company, Schenectady, New York

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Several forecasters project significant shortages of doctoral engineers, physical scientists and math and computer scientists through much of the next decade. While my crystal ball isn't clear enough to anticipate demand with certainty, it does tell me that there are likely to be real problems in maintaining sufficient numbers of top quality researchers for both industry and academe, particularly if we want to maintain a predominantly American faculty.

Industry hires the majority of new PhD engineers, physical scientists and computer scientists, while most life scientists work in academic settings. In less parochial moments, corporate recruiters realize that without top notch PhD faculty in the universities, there will be few new, well trained candidates for corporate research labs. Nonetheless, when there are fewer PhD graduates than are needed to fill all competing demands, industry usually wins the competition, because it has more money to offer.

When a shortage of candidates exists, various compromises are made. Bidding up salaries is one way for some of the employers to hire those they want. In fields such as engineering, physics and computer science, where the proportion of foreign citizens among American PhD graduates is very high, employers often go to considerable expense and effort to retain and employ foreign graduates whose student visas are no longer renewable. This is not an option for employers working principally on classified defense contracts requiring all workers to be U.S. citizens.

Another way to increase the number of available PhD researchers is to provide support to outstanding students while they earn a doctorate - and industry does provide considerable assistance of this kind. But this requires a longer term approach, and industry is not always certain of what its needs may be when the supported students become available.

Some of these options are not going to be as available in the future as they have been in the past. The new immigration law, for example, sets a five year limitation on renewal of temporary work permits. Increasingly, foreign countries want their brightest students to return home after acquiring an American doctoral education. The number of American young people of college age is decreasing, and their interest in majoring in these fields is declining. For these, and other reasons, I believe that the competition for doctoral natural scientists and engineers is likely to increase considerably over the coming decade.

One reason that shortages appear far more likely than surpluses is the drop in quality of pre-college education, particularly in math and science, that occurred during the 1970s for a substantial fraction of the nation's youth. America has been accustomed to drawing our college population, and particularly our science and engineering students from a growing pool of well-prepared mostly white and mostly male applicants. There were plenty of them

in the baby boom generation, so there seemed little reason to be concerned about an under-supply just because girls and blacks and Hispanics and the rest of the non-college-going segment of our youth weren't doing so well in math and science.

But the questionable preparation of a significant segment of the dwindling pool of tomorrow's young adults, whose racial composition also is changing quite rapidly, is no longer tolerable. Today's undergraduate students must provide tomorrow's faculty replacements and industrial research leaders. They are the teachers and research mentors of the students of the next century. So what happens now and over the next few years will reverberate not only through the 1990s, but for decades to come.

Our college-age population is dropping rapidly, and will fall a total of 26 percent by 2005. Because of that change, we can expect to have fewer baccalaureate graduates in science and engineering over the next two decades than we have had since 1970. Although total college enrollments have not dropped substantially during the first several years of the decline in the college age population, natural science and engineering graduates typically come from this age group, and not from the part time and returning students who have held other enrollment figures steady.

Bachelor's level science and engineering degrees peaked in 1974, dropped, and then rose again, fueled by rapid increases in engineering awards. But the percent of S/E baccalaureates attaining PhDs seven years later continued to drop from almost 12% in 1972 to below 7 percent in 1987.

Doctorate awards in the natural science and engineering fields peaked even earlier than bachelor's degrees - in 1971, and then dropped through 1977 before starting up again, as shown in figure 1. By broad field, increases in life sciences PhDs began late in the seventies, peaking in 1982. The number of doctorate awards in the physical sciences and engineering show fairly sharp increases since 1980.

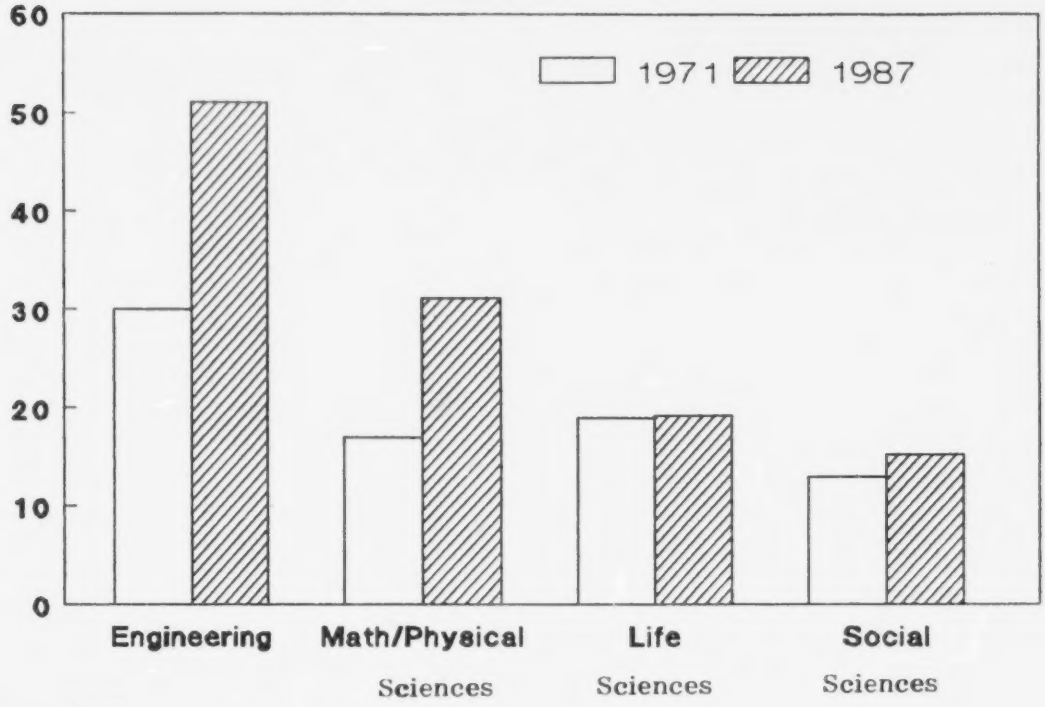
But these increases are deceptive because the composition of the graduating class also changed. The percentage of the new PhDs that were awarded to foreign citizens doubled between 1970 and 1987 in engineering and in the physical and mathematical sciences and foreign citizens were responsible for all of the 1980s resurgence in both these broad areas (figure 2). By 1987, almost one third of all doctorates awarded by U.S. universities in the physical and math sciences, and more than half of those in engineering were awarded to foreign citizens. There were minimal changes in the proportions of foreign students among life and social science recipients.

Some of the foreign PhD recipients have already obtained permanent visas by the time of the degree award, as can be seen in figure 3 among the engineers, where more than half of all doctorates since 1980 have been earned by foreign citizens. In addition, about half of the foreign doctorate recipients ultimately stay here and become a part of the U.S. work force.

But even if all of our foreign graduates wanted to stay here, it is foolish to assume that an American Congress would make it possible for them to do so, even under the difficult criteria now in effect. Substantial groups of Americans, including particularly a very vocal faction of the engineering

Percent of New PhDs Awarded to Foreign Citizens, 1971 and 1987

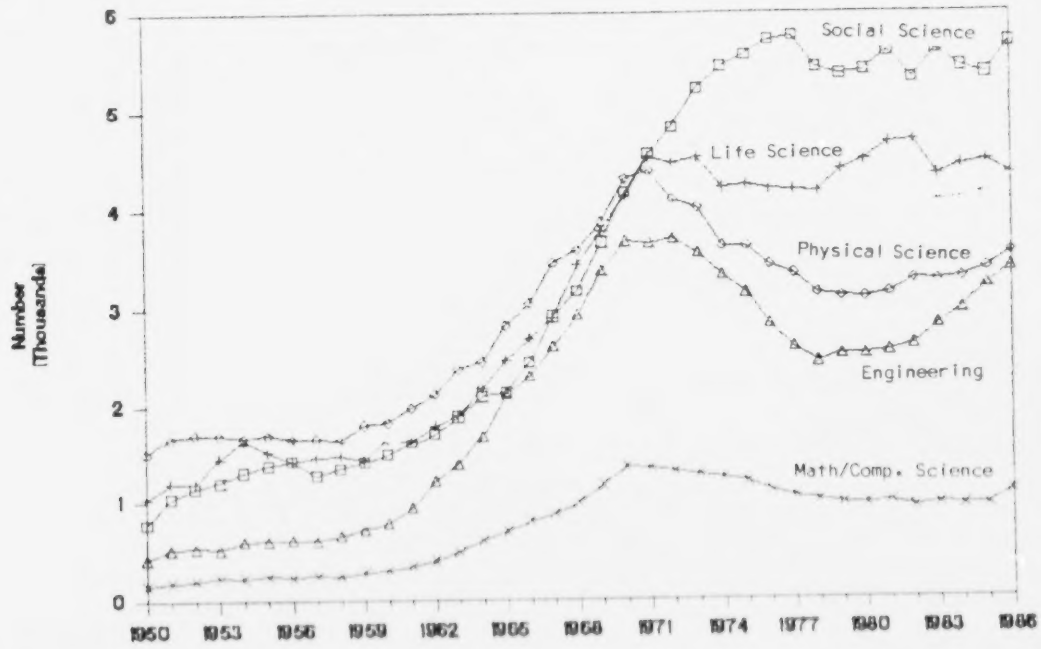
Fig. 1



Source: NRC

S/E PHD AWARDS BY FIELD 1950 - 86

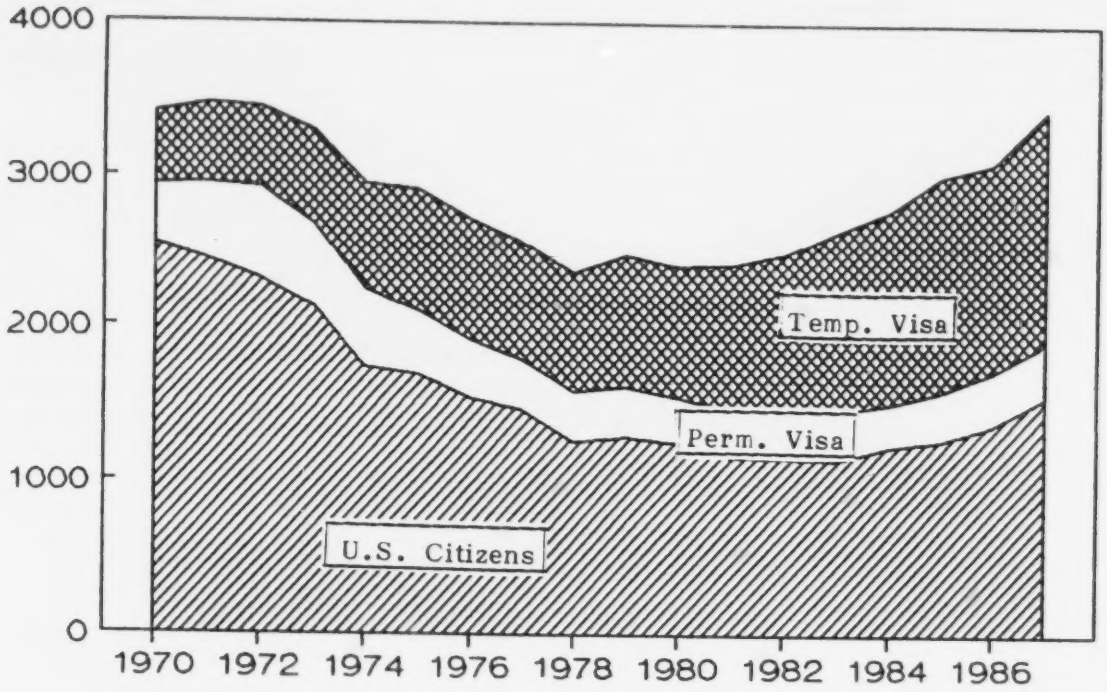
Fig. 2



Source: NCES

Fig. 3

CITIZENSHIP OF ENGINEERING DOCTORATE RECIPIENTS, 1970-1987



Source: NRC

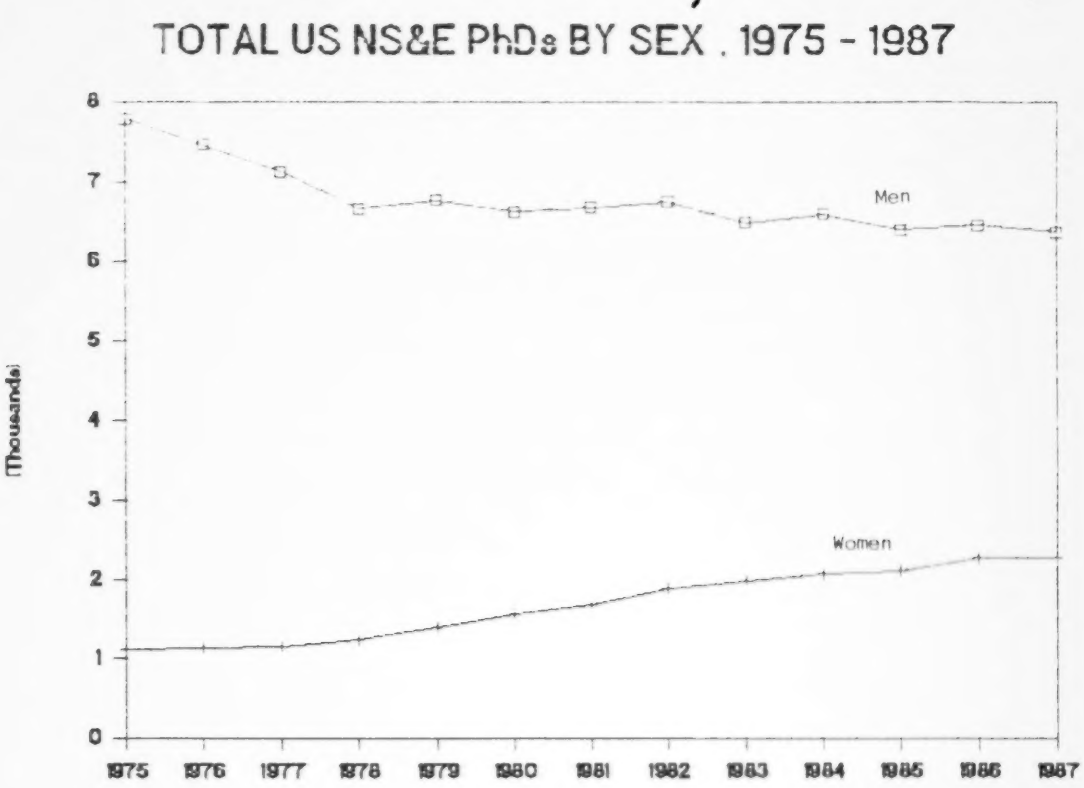
community, believe that U.S. employment of foreign graduates brings American salaries down, and increases American unemployment, although there is no statistical basis for either of these assertions.

The number of natural science and engineering doctorates earned by Americans has fallen for a decade, because the slowly increasing numbers of women earning such degrees have not made up for the continuing drop among American men (fig. 4).

As shown in figure 5, there has been an increase in women faculty in all science and engineering fields over the past decade, but even by 1985, the proportion in engineering was only 2%, and in the physical and math sciences, less than eight percent.

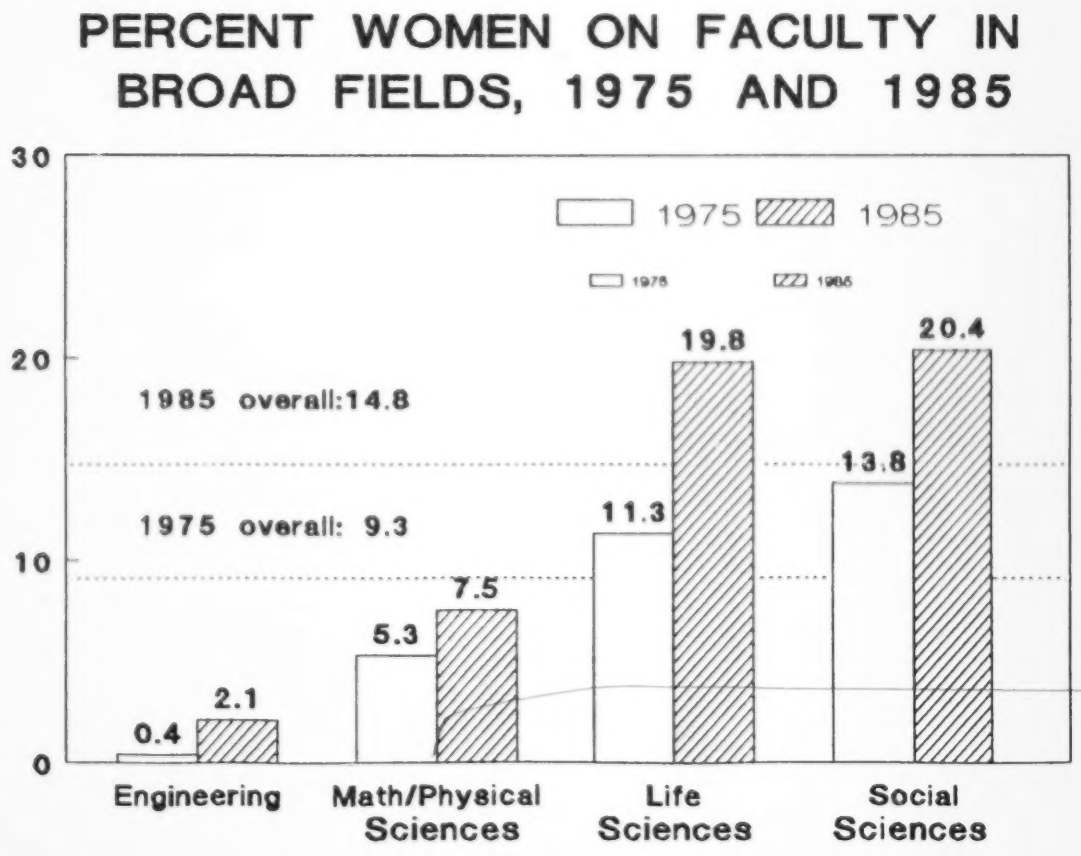
Our utilization of foreign graduate students as teaching assistants and faculty, an increasingly common practice in engineering, physics, chemistry, computer science and mathematics, adds to one problem while solving another. In addition to the obvious language barriers, which affect American students

Fig. 4



Source: NRC

Fig. 5



Source: NSF

of both sexes, the cultural backgrounds of the foreign students often clash with the American view that women are capable and worthy students in science and engineering.

Because the fields with the highest foreign component among the teaching assistants and faculty are also those with the fewest women faculty, American women students have no place to turn for help when these problems occur. Unless more women earn degrees in these fields, the proportion of women faculty will not rise. At the same time, without more women faculty, women students are discouraged from entering. Foreign teaching assistants and faculty are by no means the only source of men who may question the appropriateness of engineering careers for women!

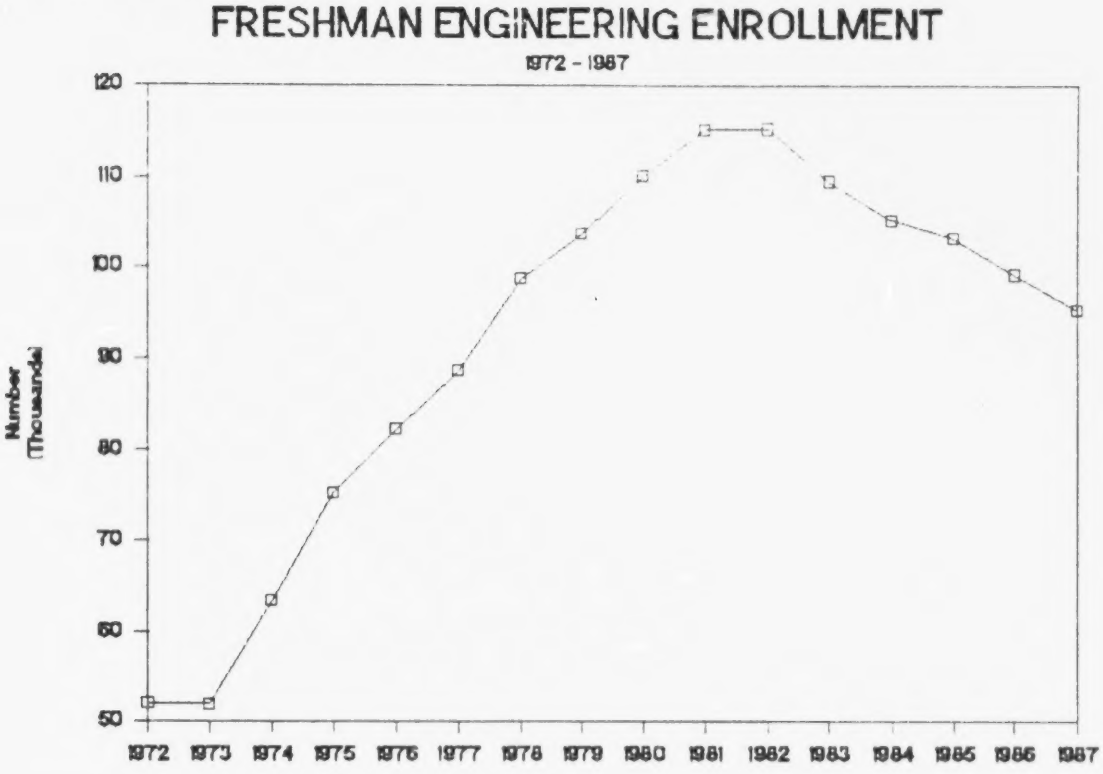
There is no question at all that the addition of foreign scientists and engineers to our American melting pot has been valuable. These immigrants have made inestimable contributions to our nation, to industry and particularly to our universities - as graduate students, as teaching and research assistants, and in many cases as faculty researchers and teachers. But our increasing reliance on this shaky source is dangerous, because we cannot continue to count on their wanting to or being allowed to stay here. Their own countries increasingly offer opportunities for them to utilize their advanced American education, and some, like China, for example, have become so concerned about the brain drain that students now beginning U.S. graduate study must, in effect, post a substantial bond before leaving to assure their return.

However, we also need to get more American PhDs in these research fields. One way is to increase the number of undergraduates, and thus bachelor's graduates. But because of the shrinking size of the nation's 18-year-old population, a drop in undergraduate enrollments in these fields is almost inevitable. For example, as shown in figure 6, freshman enrollment of both sexes in engineering peaked in fall 1982 and has already fallen 17% - or 20,000 students in five years. The female segment of the class is already down 21%, showing us quite clearly that the growth in percentage of women choosing engineering stopped at only one fifth of parity with their share of the population. Unfortunately, we have no comparable measure for viewing changes in freshman enrollment in other fields.

But we do have a long time series measure of freshman interest in majoring in one or another field of science or technology, based on Alexander Astin's annual study of the American Freshman class. It shows us that, for both sexes, freshman interest in science majors has dropped a third over the past two decades, with the proportion of the freshman class planning majors in any natural science or engineering field falling from 21.3% to 14.4%. Hardest hit is mathematics, dropping by more than four fifths in the past 22 years, from 4.5% of freshmen to 0.6%.

More recently, freshman interest in an engineering career (and thus, plans to major in engineering) fell by more than a fourth between 1982 and 1987, from 12% of the entering class to 8.5%; while the preference for computing careers declined by more than two thirds, from 8.8% to 2.7% during this same five years (figure 7). That interest has not been transferred into other fields of science, for we also see a drop in the proportion of the freshman class planning to major in life sciences, the

Fig. 6



Source: EMC

Fig. 7

Source: Cooperative Institutional Research Program

physical sciences and mathematics. Only the social sciences show any gain - and this is not an area of potential shortage. The change for students is into business majors. Thus, we face a diminishing class size, and a smaller proportion of the shrinking group than in two previous decades choosing a major in natural science or engineering.

Based on the announced plans of freshman, which show a good correlation with degree awards four years later, production of NS&E baccalaureates will drop substantially, even by 1990 (fig. 8). Baccalaureates are, of course, the essential first step toward doctorates.

You are all aware of the increasing minority component of our school age population. In 1982, about one fourth of school age youth were minorities. By 1988, about 30% of U.S. 5-17 year olds are black, Hispanic or Asian. The most conservative projection of the Census Bureau shows us that by 2020, half of our school-age children will be black, Hispanic, American Indian or Asian American (fig 9).

California schools will have a minority majority this fall, joining the school populations of Hawaii, New Mexico and Alabama. By next fall, the majority of Texas school-age students will be members of minority groups. Obviously, we need some new words in our language! The Asian youngsters, who typically choose science and engineering in greater frequency than other racial or ethnic groups, are only a small fraction of the minority population. We are already far behind in educating proportionate numbers of black, Hispanic and American Indian students even to the baccalaureate level.

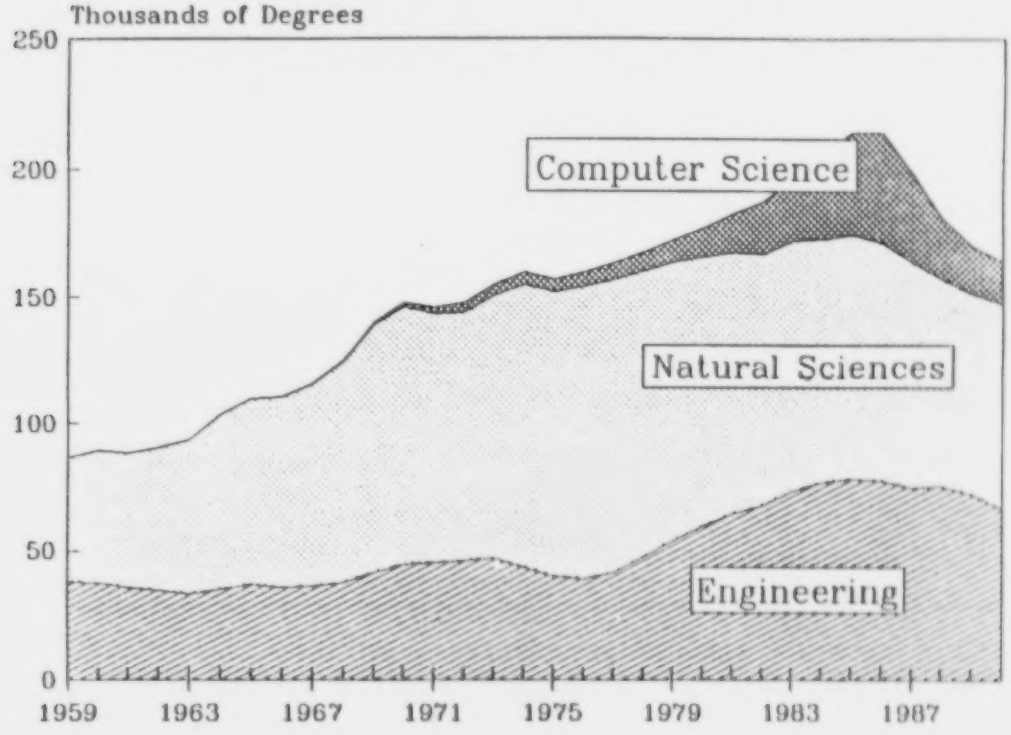
At the PhD level, where researchers and faculty are being prepared, the minority numbers are miniscule. Although they make up almost one fourth of the American age-30 population, blacks, American Indians and Hispanics combined earn only 2 percent of engineering, math and physical science doctorates, and only slightly higher proportions in life and social sciences.

Black faculty members in the sciences, even including the social sciences, are largely invisible. They constitute less than one percent of engineering faculty, and less than 3 percent of physical science faculty. Further, as shown in figure 10, except in the social sciences, the increase over the past decade is insignificant. Here the problem of lack of role models is dramatically underlined. How can we communicate to growing numbers of minority youngsters that research or teaching careers in science and technology are rewarding and possible for them? We haven't been able even to add substantially to the minority population among baccalaureate graduates in natural science and engineering fields - much less PhDs.

So there probably will be fewer American PhDs produced. How do we know that we'll need more doctoral scientists and engineers that we're likely to get if we don't intervene? The answer is, of course, that we don't know. But if we assume that the nation will continue to compete technologically on a global scale with other countries having serious research and development programs, we can also assume that we probably will need at least as many new doctoral researchers as we have been getting for the past few years. PhD production in natural science and engineering has averaged about 13,000 new PhDs per year since 1970, with about two fifths being foreign nationals.

NS&E BS Production
[Showing Expected Effects of Freshman Intentions]

Fig. 8

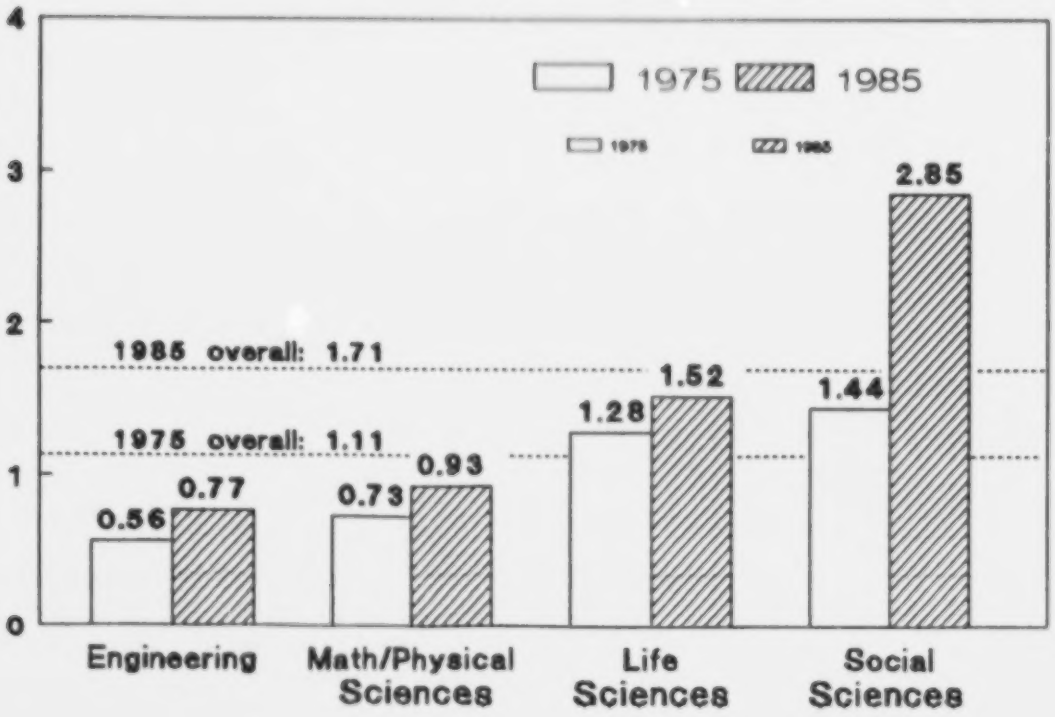


Source: NSF

Fig. 9

Source: Census Bureau

Fig. 10



Source: NSF

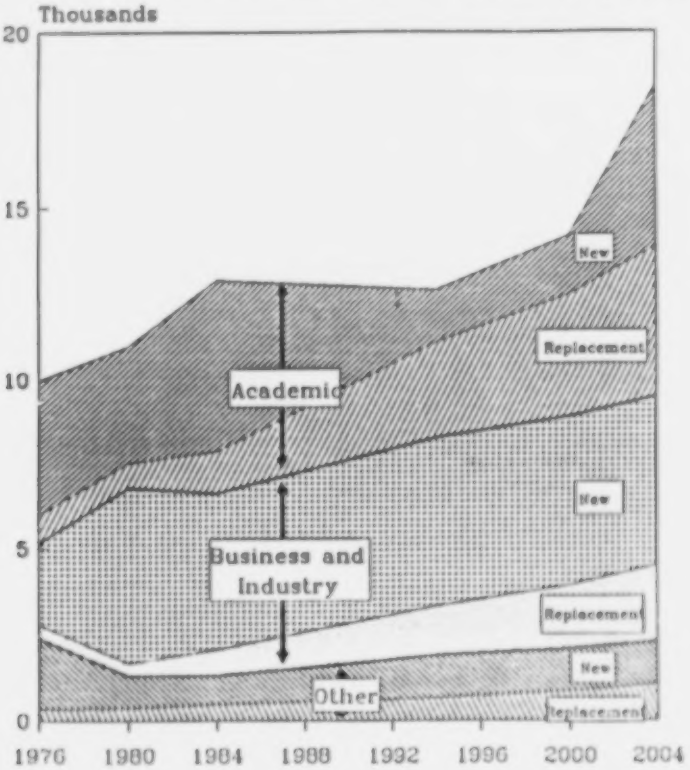
The National Science Foundation projects available positions for these specialists to 2004, differentiating both by general employment source and by replacement vs. new positions (fig. 11). These projections indicate a combined need for about 18,000 new NS&E PhDs by 2004, compared with 1987 production of 14,485 including foreign students. Only 8,600 American citizens earned NS&E PhDs in 1987 - about half the indicated demand in 2004.

How realistic are these projections? On the academic side, replacement needs appear to be right on the mark. During the decade from 1975 to 1985, American science and engineering faculty aged significantly (fig. 12). In engineering, although hiring of new and primarily foreign faculty has kept pace with hiring of young faculty a decade earlier, the bulk of doctoral engineers employed in colleges and universities grew ten years older. More than a third of American science and engineering faculty members already are over age 50, and a fourth of teaching faculty will reach age 65 by 1995.

Replacement needs in industry probably will increase, just as in academe. The NSF projections assume no further increases or decreases in new demand in either industry or government.

Available PhD Positions for Natural Scientists and Engineers

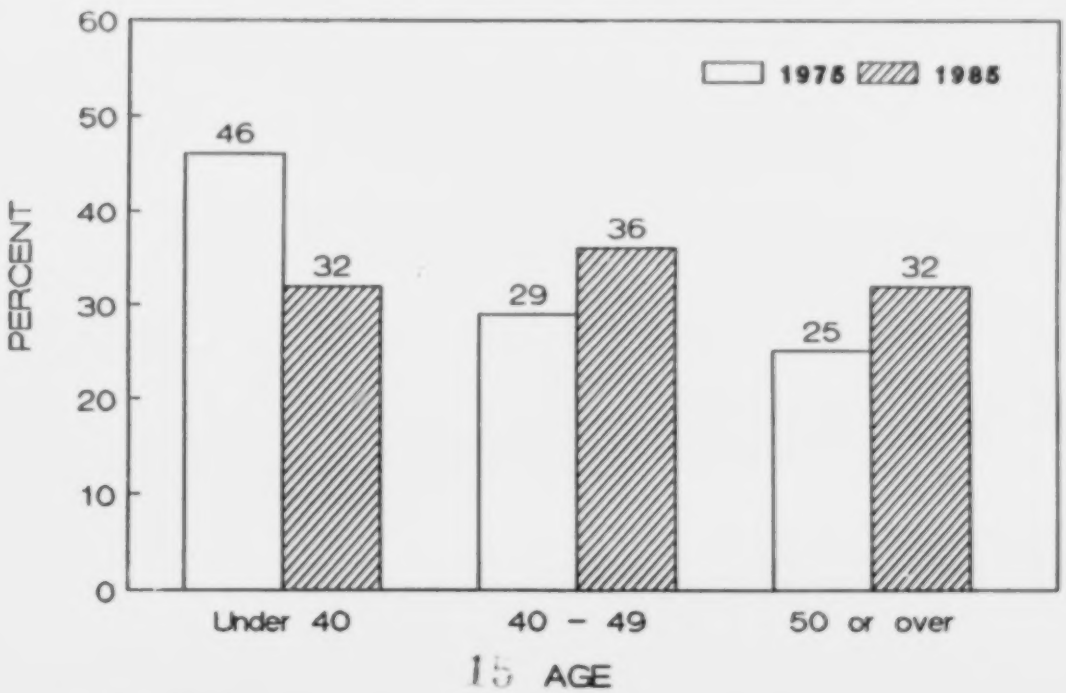
Fig. 11



Source: NSF

AGE OF ACADEMIC PHD SCIENTISTS AND ENGINEERS, 1975 AND 1985

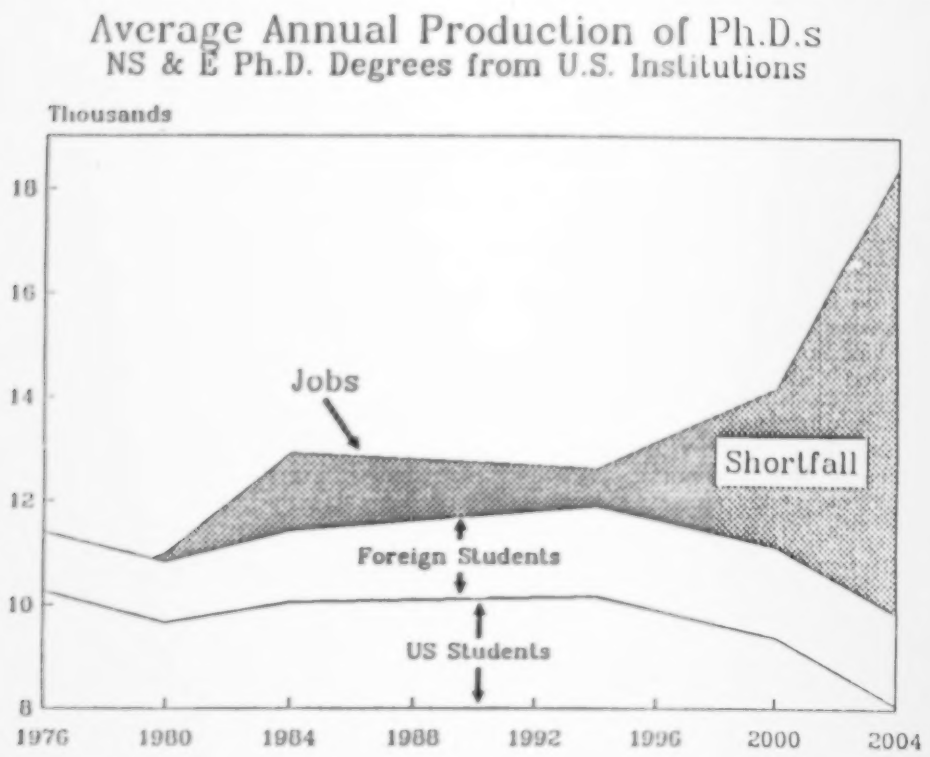
Fig. 12



Source: NSF

The increasing demand, when related to a diminishing number of doctoral candidates, even with the present absorption of foreign students, results in a substantial shortfall of natural science and engineering PhDs by 2004 according to the National Science Foundation projections (fig. 13).

Fig. 13

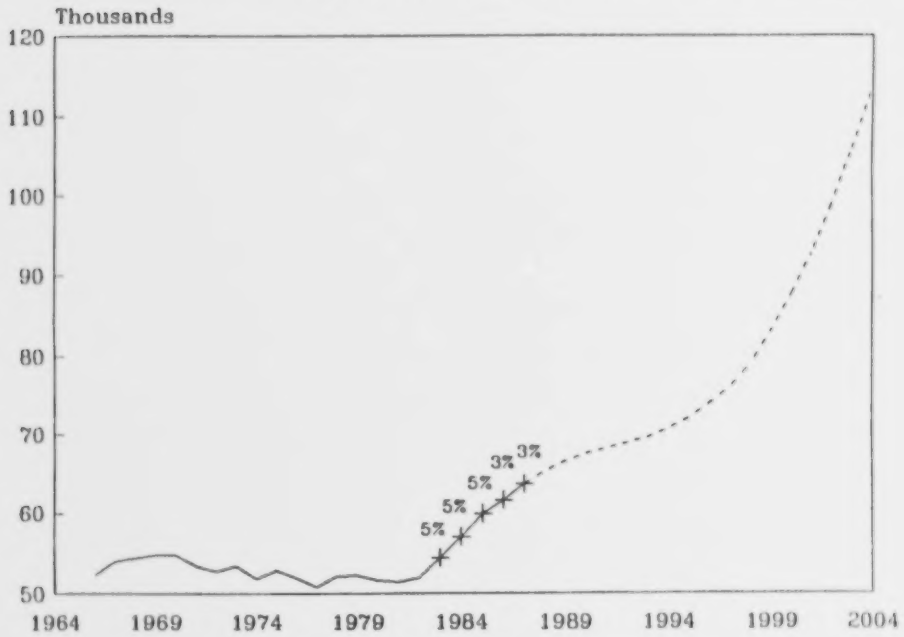


Source: NSF

There is no present evidence that industrial research managers expect to cut back employment of doctoral scientists and engineers, although it is important to remember that **demand** is not the same as **need.** Demand is need with funding applied, so that salaries can be paid. And if the National Science Foundation is correct, those salaries will continue to grow very rapidly. In constant dollars, salaries and fringe benefits of R&D full time employees, including those without a PhD, have been growing three to five percent per year to accommodate market demands, despite short run adjustments including deferred retirements, increased foreign participation, etc. Such adjustments have not offset the increasing demand for these workers, and NSF sees a continuation of this trend even if there is little or no growth in future demand (fig. 14).

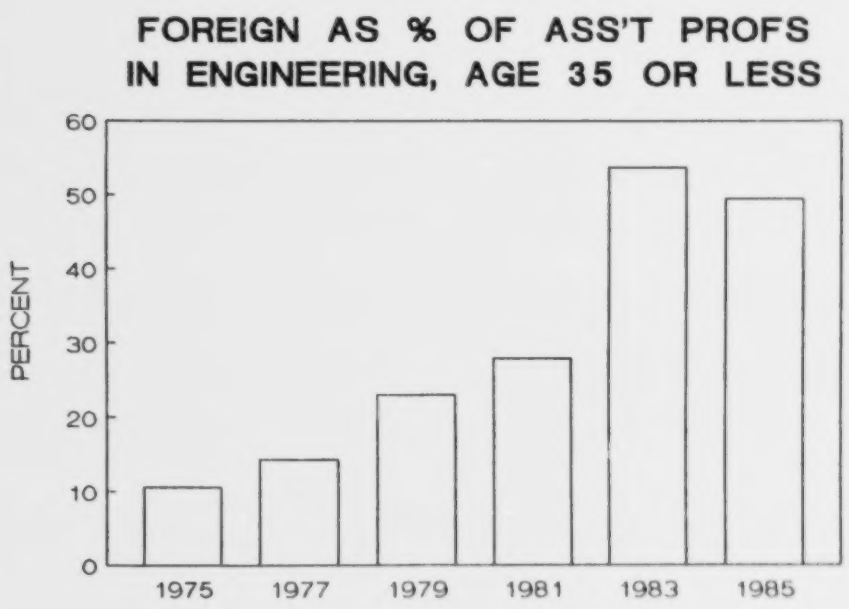
How has the shortfall been met? In engineering, the proportion of new PhD graduates employed in industry has remained at 59% for more than a decade. In the science fields, the proportion of new doctorates going to industry increased substantially in every field. In part, this was because there were no places for them in academe, which had a young, tenured faculty in science in 1975.

Fig. 14



Source: NSF

Fig. 15



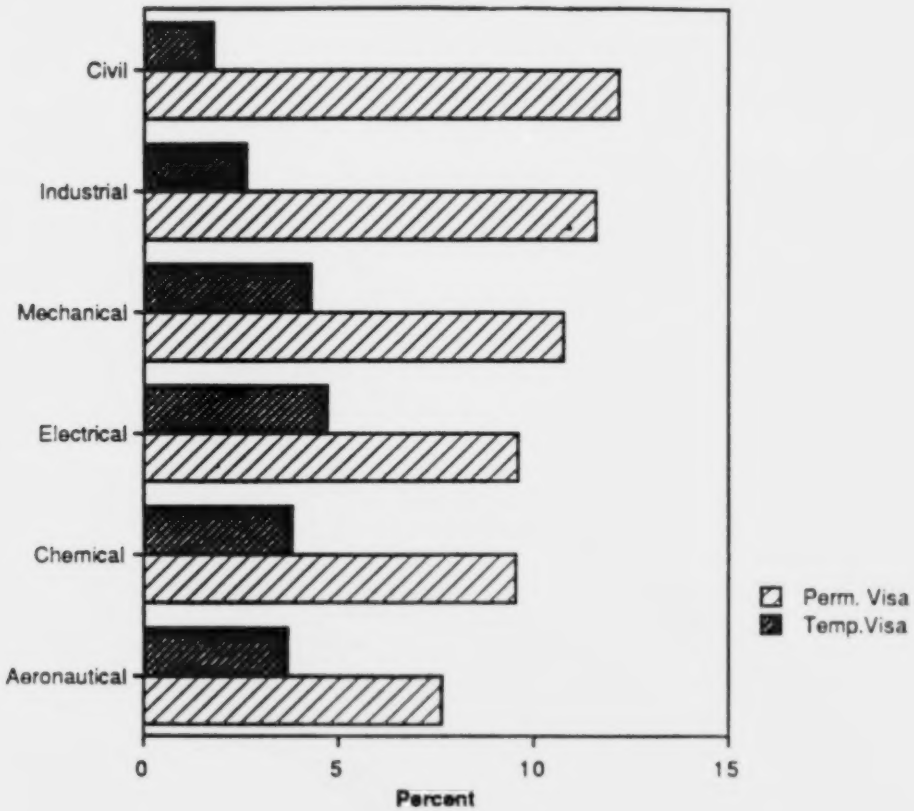
Source: NRC

But that has changed. In engineering, the increasing industrial employment of new PhDs left shortages to be absorbed principally by academic institutions. As demand for new faculty continued upward and supply of American PhDs continued to drop, foreign graduates, most of them on temporary visas, were hired to fill the openings. By 1985, more than half of the assistant proessors in engineering who were under age 36 were foreign nationals (fig. 15), reflecting the fact that more than half of all new PhD awards in the U.S. in engineering since 1980 have been made to foreign citizens. This says something very good about the quality of American graduate schools in attracting the best and the brightest from other countries. It says something very frightening about the dropoff of American graduate students in this area.

The addition of so many young foreign graduates resulted in turn in a steadily rising foreign concentration among total engineering faculty in all fields (fig. 16). Note that many still have temporary visas, some of them renewed several times.

FOREIGN AS A PROPORTION OF ALL ENGINEERING FACULTY IN PHD INSTITUTIONS BY TYPE OF VISA 1986

Fig. 16

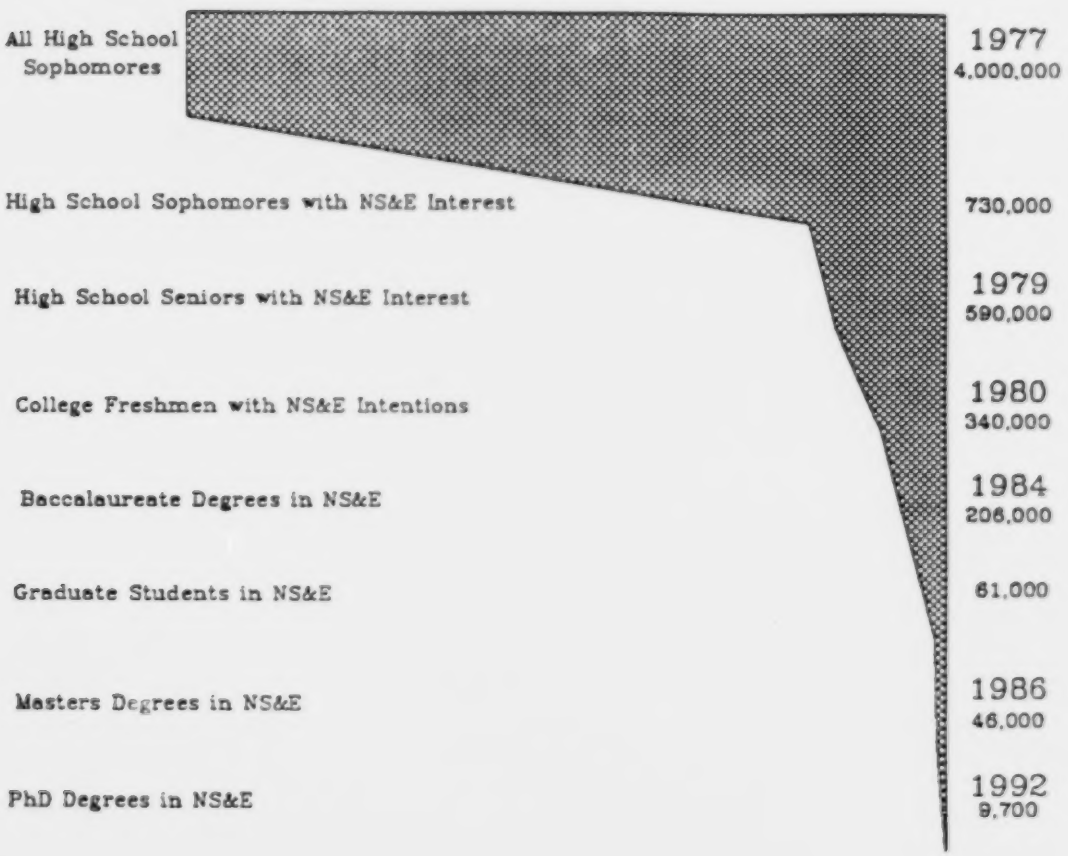


SOURCE: National Science Foundation.

Unless something is done to change the pattern, it appears obvious that there will be at least selective shortages of PhDs in the natural sciences and engineering. The constriction of the talent pool year after year as students move through high school and college and to graduate school is the result of a selection process that presently produces one doctorate in natural science or engineering from every 412 high school sophomores (fig. 17). In 1977, there were approximately four million high school sophomores. About 750,000 of them show an interest in NS&E fields, and 590,000 held that interest through high school. Only 340,000 entered college planning to major in one of these fields, and 206,000 achieved a bachelor's degree in NS&E. From this group 61,000 went on to graduate school, 46,000 earned as master's degree in 1986, and 9,700 will probably earn a PhD in 1992.

Women are considerably more likely than men to drop off the NS&E track at various stages, and minority students are less likely than white students to persist in these fields. So with a smaller population, let's look ahead at the composition and characteristics of a potential PhD class - the class of 2012..

Fig. 17



Source: NSF

This is also the freshman class of the year 2000, made up of the children born in 1982 who have just started the second grade.

- One in four of them lives below the poverty line.
- Half will live in a single parent home before they finish high school.
- Almost one third of them are black, Hispanic, Asian or Indian.
- Only one third of them are white, non-Hispanic boys.
- One in eight has a physical or emotional handicap.
- One in 12 does not yet speak English very well.
- The age cohort is 14% smaller than the PhD cohort of 1987.

Among the 14,500 PhD recipients in natural science and engineering in 1987:

- Only three fifths were American citizens.
- Seven of every ten of the Americans were white males.
- One in four was a white woman.
- One in fourteen was a member of a minority group.

It is apparent that intervention is needed, and that it cannot be delayed for another decade or two.

NSF has suggested intervention points and times for increasing the number of natural science and engineering doctorate awards in 2008 to the number anticipated in 1992. This includes interesting more students in grades 1-10 in science and math, and doing it now. We need to retain in the natural science pipeline those youngsters still eligible by virtue of their math-taking preparation who are now in grades 11-12. By 1990, we must be retaining more interest in science and engineering among college students, and by 1994, we must attract and retain more PhD candidates.

If we fail to take action now, doctoral recruiters in a decade or two are likely to find it much more difficult to hire the researchers they need. Other alternatives include those we have always used - hiring persons with different or lesser qualifications than is desired or preferred; attracting and importing individuals trained in other countries; or importing the research from other companies or countries - i.e. outsourcing.

I am indebted to Harold Hodgkinson for a final reminder to today's recruiters who expect to be retired by the time the competition gets too tight. You may want to remember that of the three workers who will be paying for your social security checks with their wages, at least one will be a woman, and one will be a minority. It behooves all of us to do what we can today to make sure that these workers will earn enough to be able to support us appropriately in our retirement years.

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PROFESSIONAL WOMEN AND MINORITIES, A Manpower Data Resource Service, Seventh Edition, December 1987. Members - $75; Non-members - $85.

A comprehensive reference book of manpower data presented in approximately 400 tables and charts, with breakouts by sex and/or minority status. Current and historical data on enrollments, degrees, and the general, academic, and federal workforce by field and subfield are supplemented by a section detailing federal laws and regulations on affirmative action, and annotated list of recruitment resources for women and minority professionals, by field; a comprehensive cross index; an extensive bibliography. Earlier editions provide additional trend data.

SALARIES OF SCIENTISTS, ENGINEERS AND TECHNICIANS, A Summary of Salary Surveys, Thirteenth Edition, October 1987. Members - $35; Non-members - $45.

A 224-page report presenting detailed information from more than 50 salary surveys on starting and advanced salaries in industry, government and educational institutions with breakouts by field, highest degree, sex, years since first degree, age group, category of employment, work activity, type of employer, geographic area, academic rank, Civil Service grade and grade distribution, and level of reponsibility, with some comparative salary data in non-technical fields. Data are provided by sex and/or minority status where available. Includes both published and previously unpublished data on salaries for the period 1985-1987. Text highlights 247 tables and 3 charts. Earlier editions of the continuing series provide longitudinal data, and are available at half price.

THE TECHNOLOGICAL MARKETPLACE - Supply and Demand for Scientists and Engineers, May 1985. Member - $20; Non-Member - $25.

This 54-page report, which includes over 50 tables and charts, examines past, present and future imbalances in the supply of and demand for scientists and engineers. The supply is assessed by source and by field, and compared with current and short range demand for new and experienced graduates, including assessment of the increasing participation of women and foreign nationals in degree output. Surveys projecting supply/demand imbalances over the next decade are examined and compared. [The 1982 edition is available for $10.]

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OTHER CURRENT PUBLICATIONS (continued)

of the COMMISSION ON PROFESSIONALS IN SCIENCE AND TECHNOLOGY

COMPETITION FOR HUMAN RESOURCES IN SCIENCE AND ENGINEERING IN THE 1990s, May 1988, Members - $15; Non-members - $20.

Proceedings of a symposium where experts discussed demographic changes, present status and required agenda to meet the upcoming challenges of national and international competition; includes charts and tables.

SCIENTIFIC MANPOWER - 1987 AND BEYOND, January 1987. Members $15, Non-Members $20.

Proceedings of a Symposium examining the effect of today's federal and corporate budgets on tomorrow's science and engineering manpower.

THE INTERNATIONAL FLOW OF SCIENTIFIC TALENT: Data, Policies and Issues, September 1985. Members - $12.50, Non-Members - $15.

The Scientific and Engineering Manpower Commissions, meeting at the National Academy of Sciences, explored the increasing participation of foreign nationals in this country's educational institutions and workforce. Tables and charts supplement the text.

OPPORTUNITIES IN SCIENCE AND ENGINEERING - A Chartbook Presentation, Second Edition, November 1984. Members - $12.50, Non-Members - $15.

This 96 page presentation includes information on the present supply of men and women scientists and engineers, detailing such characteristics as their educational preparation, their labor force participation and employment opportunities, and their starting and advanced salary levels. The future supply of and demand for scientists and engineers is examined by field under different scenarios for various periods in the future. Each page of text is accompanied by a full page chart outlining some of the statistical information included. The charts are suitable for reproduction.

GUIDE TO DATA ON SCIENTISTS AND ENGINEERS, April 1984, free to libraries.

This 275 page reference book consists of three indexes to science and engineering manpower data published by 49 organizations concerned with some phase of science or engineering manpower. The Bibliographic Index describes each publishing organization, outlines the manpower surveys it conducts, and lists detail of data tables in each of its publications covering 1973-1983. A Field Index and year of Data Index are quick guides for any data characteristic, which reference back to the Bibliographic Index.

The Commission on Professionals in Science and Technology, (formerly the Scientific Manpower Commission), A Participating Organization of the American Association for the Advancement of Science, is a nonprofit corporation with various categories of membership open to professional societies, corporations, institutions and individuals who share its interests and objectives. Commissioners are appointed by member Societies and Corporations.

The Commission is charged with the collection, analysis and dissemination of reliable information pertaining to the manpower resources of the United States in the fields of science and technology; promotion of the best possible programs of education and training for potential scientists, engineers and technicians; and the development of policies of utilization of scientific and technological manpower by educational institutions, industry and government for optimum benefit to the nation.

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